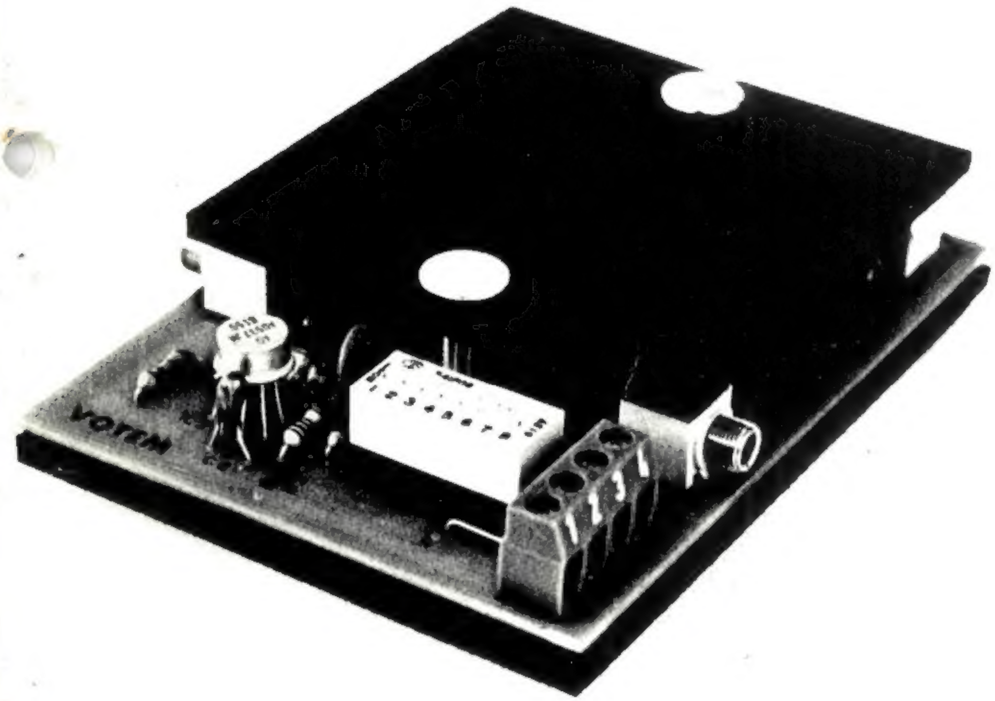
VOTEM
USER'S MANUAL



Down East Computers
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CONTENTS

VOTEM
Analog Interface
for the Timex/Sinclair Computer

DOWN EAST COMPUTERS
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INTRODUCTION AND OVERVIEW OF VOTEM'S CAPABILITIES:

Congratulations! Welcome your computer to the real world. No longer does your computer have to rely on information that was entered from a keyboard. With VOTEM your computer can acquire its own information directly from the outside world. VOTEM is an inexpensive analog interface, providing the missing link between a computer and the outside world. VOTEM is actually a complete package, consisting of the necessary hardware and software to turn your computer into a voltage and temperature measurement system. However, we will often refer to the hardware module alone as VOTEM throughout the course of this manual.

We have combined several other useful features in the VOTEM package. The low-power, self-contained unit also provides you with two means (audio and visual) of monitoring the signal as you load programs from tape. Also, the tape signal is amplified and conditioned before being sent to the computer, resulting in more reliable program loads. With this feature you should be able to use a lower volume setting on your recorder and perhaps be able to load programs from tapes which previously would not comply. Finally, the conditioned input can also be used as a frequency meter input. The software provided enables a 3.25 MHz Sinclair computer to measure pulse rates beyond 30 KHz.

The absolute accuracy of your voltage and temperature measurements will depend on several things, the most important of which is calibration. The calibration is done in software. It is important that you understand how VOTEM works in order to realize its potential. The next section describes the principle of operation. Later we will discuss the necessary software and the calibration procedure.

If you purchased a kit and you are like most people, you will probably want to get your hands dirty and start soldering components to the circuit board immediately. If you would like, skip the next section for now but do read it before you go on to the calibration section. A thorough understanding of VOTEM's operation is essential for maximum performance. Also, please read carefully the section BEFORE OPERATING before applying power to VOTEM.

TUTORIAL AND THEORY OF OPERATION

VOTEM employs a simple and efficient yet commonly overlooked method of analog to digital conversion. The method is based on a device called a voltage to frequency converter (or simply denoted V/F). The "ideal-perfect" V/F converts some input voltage to a frequency which is exactly proportional to the input voltage. For example, an input voltage of 0 V would be converted to a frequency of 0 Hz and a voltage input of 0.1 V would cause the V/F to produce a stream of pulses at exactly 100 Hz. An input of 0.5 V in would produce a frequency of 500 Hz and so on. The ratio of voltage-in to frequency-out is set either by the manufacturer of the V/F or by the user with resistor/capacitor combinations. A plot of frequency-out vs. voltage-in of an ideal V/F would be a perfectly straight line. Of course it should be realized that there is no such thing as an ideal voltage to frequency converter. (In fact there is really no ideal anything in the world of electronics.) The term used to describe the amount of deviation from the straight-line, voltage-frequency plot of a real world V/F is 'nonlinearity'. Many factors can affect the nonlinearity of a V/F including the inherent quality of the V/F module and also the type and quality of the passive components (resistors and capacitors) used. We have chosen one of the best integrated circuit voltage to frequency converters available. In addition all critical passive components are of premium quality in order to minimize the nonlinearity of the V/F section of VOTEM.

VOTEM has a V/F. Hence, in order to measure voltage, we need an instrument that can measure frequency. High quality frequency meters can cost hundreds, even thousands of dollars. Fortunately, with the help of a short machine-language program we can use our computer to measure the frequency of pulses coming from VOTEM. And best of all, VOTEM connects directly to the cassette tape input of the ZX80/81, so there are no special hardware modifications. Also, the edge connector on the back of the computer is left free for additional devices such as the RAM memory pack and printer.

Actually, we need a little more software than just the machine language program mentioned above. The machine language program is called by a USR function within a BASIC program. The machine language routine returns with a count-value which is proportional to the frequency of pulses appearing at the cassette input. The USR function is then equal to that count-value. The value can then be handled conveniently by the BASIC program. The BASIC program can provide the necessary number crunching to convert the count into a voltage which can then be displayed or processed further. By using the appropriate equations in the BASIC program the voltage can be expressed and displayed in units of volts or millivolts or both.

The count returned by the USR function is related to the system clock frequency. For reasons of economy Sinclair decided to use a somewhat low quality ceramic crystal oscillator. This is revealed by the fact that the system clock may be off of 3.25 MHz by as much as several percent. Now you should not be alarmed if you find that your system clock is 3.21 MHz while your friend's was measured at 3.26 MHz. For most applications the exact system clock frequency is not relevant. In this application it is. In order to measure absolute frequency you must know your system clock frequency accurately. You should only need to determine it once since it is relatively stable and free from drift. We describe a method of calculating the system clock frequency later. If all of this does not make much sense don't fret. You only need to know your system clock frequency accurately if you are going to measure frequency. Remember the count returned from the machine language program is proportional to the frequency input to the computer which is proportional to the voltage input to VOTEM. You can still measure voltage without knowing your system clock frequency.

Notice the absence of trimming potentiometers on VOTEM. This is because all calibration is done in software. Why is calibration necessary? Because of the slight differences in components used, one VOTEM may not produce a pulse stream of exactly the same frequency as another even though identical voltages may be present at their inputs. Also, different computer systems will have slightly different system-clock frequencies and will produce different results. Therefore, each particular VOTEM/computer system is unique and must be individually calibrated. There are really only two kinds of adjustments necessary: gain and offset. The gain of the V/F is defined as the units of frequency change per unit of voltage change. It is roughly 25 Hz/mV. So a voltage input of 1V should yield a frequency output of about 25 KHz. The offset is the residual frequency resulting from zero volts input. This will probably be negligible. It is very easy to adjust the apparent gain and offset in software and that is exactly why there are no trimpots on VOTEM. We will talk more about calibration of VOTEM later.

Now what about temperature? VOTEM can measure temperature in two entirely different ways. It just so happens that the V/F comes equipped with its own thermometer output. The voltage at this output tracks absolute temperature [*] at 1 mV/degree. That is, it has a voltage output which is proportional to the absolute temperature. By merely connecting the voltage input of the V/F to the temperature/voltage output we have an absolute temperature to frequency converter. The other way of measuring temperature with VOTEM is by using a probe made with a solid state temperature sensor. The voltage drop across the sensor is proportional to the absolute temperature. Notice I said that the voltage 'drop' is proportional to temperature. This means that our two methods of relating temperature and voltage are entirely different. One is proportional. The other is inversely proportional. Don't fear. We have software to deal with these kinds of differences. By using appropriate equations in the BASIC program we can handle the different voltage-temperature relations. For example, we can report temperature either in Celsius or in Fahrenheit just by using the appropriate equation or we could have the screen flash "TOO HOT" if the temperature got over a certain value.

* Absolute temperature is measured on the Kelvin scale. There is no temperature lower than absolute zero (0 degrees Kelvin). The Kelvin scale uses the same increments as the Celsius or centigrade scale but it is shifted such that 0 degrees Celsius is equal to 273.16 degrees Kelvin and 100 degrees Celsius is equal to 373.16 degrees Kelvin.

KIT ASSEMBLY PROCEDURE

REQUIRED TOOLS

- Small soldering iron (not a gun)
- Fine gauge resin core solder
- Small sharp wire cutters
- Small screw driver
- Two-part epoxy cement *
- Patience and a steady hand

* Not required for kits with ready-made temperature probe

NOTES

---> Follow the instructions in the order as they appear.
---> Use only a low wattage soldering iron (15 to 30 watts).
---> Preform component leads at right angles with pliers or tweezers before inserting on circuit board.
---> After soldering trim excess leads with wire cutters.
---> Take your time. Read and think before you solder.

INSTRUCTIONS

(1) Identify all parts on the list. We recommend placing the components in there respective places on the picture of the circuit board. This makes it very easy to make sure that no parts are missing and is also helpful in locating their positions on the circuit board during actual assembly.

(2) Insert resistors R1 through R17. Turn the board over and solder all resistor leads. Trim and save excess leads with wire cutters; the leads are to be used in the later steps.

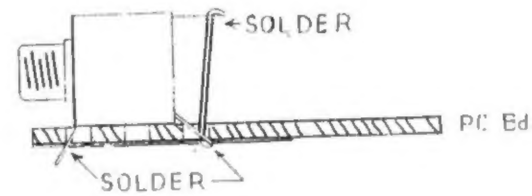
(3) Insert and solder the three jumpers J1,J4,and J5 using the wire leads saved from previous step. J2 and J3 are not used. Insert a jumper at C2.

(4) Insert and solder DIP sockets for IC1 (14 pin socket) and S1 (16 pin socket). Care should be taken to not create solder bridges between the adjacent pads.

(5) Insert and solder the diodes D1 and D2. D1 is a light emitting diode (LED). D2 is a zener diode. Note the flat side of the LED and the band stripe on the zener diode. Refer to labels on the circuit board when inserting the diodes to make sure they are mounted in the correct orientation with respect to polarity. It is possible to put these in backwards. The leads of the LED should be bent at right angles. The LED should lay on the board pointing outward as shown on the circuit board label..PA

(6) Insert miniature phone jacks JACK1 through JACK5. If

your kit contains the light tan colored jacks then the following special procedure must be applied. The light colored tan jacks are actually for panel mounting but can easily be adapted for mounting on a circuit board. Mount the jacks, with their orafices facing the edges of the board, and their solder lugs inserted into the two outside of the three holes in the circuit board. Bend the solder lugs outward so the lugs will hold the jack in place. Use one of the wire leads to connect the top solder lug to the circuit board by threading it through to the hole in the circuit board. Do this for all five jacks and then solder them in place.



Mounting phone jack to PC board.

(7) Insert capacitors C1, C3, C4, C5, C7, C8, C9 and C10. Refer to the board labels before mounting capacitors. C6 and C2 will not be used. The correct polarity must be observed on C5 and C8. Solder all capacitors in place.

(8) Insert and solder the terminal strip TB1. Trim excess leads. The numbers must face the edge of the board.

(9) Insert and solder IC2. This is a voltage regulator and it is possible to put it in backwards. Refer to the labels on the board. Do not over heat this device. It can be damaged by too much heat from the soldering iron.

(10) This step can be tricky but be cool; take a break if you need one. Remove the foam from and insert IC3. This is the V/F converter and is the most expensive component. Make "@#!$&*" sure you observe the proper orientation. The tab on the metal can is the reference point. Match it with the label on the circuit board. Insert the IC and press it in so that its top is level with the top of the jacks. CAREFULLY solder IC3 in place. TO MUCH HEAT CAN DAMAGE THIS DEVICE. Do not allow the soldering iron to contact any lead on this device for more than 5 seconds at a time.

(11) Install IC1 and S1. Again, be sure to observe proper orientation. The dot or notch on IC1 will serve as the reference. The numbers on S1 should read (1 2 3...8) from left to right when viewing that edge of the board.

(12) Assemble the unit by sandwiching the board between the two sheets of plastic. The larger sheet goes on the bottom. Fasten the three pieces together with the two binding posts and screws. Peel off adhesive backing on the four rubber feet. Apply one foot to each corner on the bottom of VOTEM.

There is no thirteenth step.
(No, we're not superstitious, just cautious.)

(14) If your kit does not contain a ready-made cable then you will have to assemble your own from the parts provided. In assembling the cable, the center conductor of the shielded wire must connect to the center conductor of the phone plug.

BEFORE OPERATING

There are several things that you must be aware of before using VOTEM. Not observing the recommended precautions can result in damage to VOTEM.

* Never connect the power cables with power applied. Always apply power last. In other words, don't plug the power supply into the wall outlet before you make connections to VOTEM.

* Certain switch combinations can cause trouble. Only one in each of the two groups of the following switch positions should be on at a time.

```
    1  2  3  4  5  6               7  8
    \              /               \  /
  ONLY ONE SHOULD BE ON.         ONLY ONE
                               SHOULD BE ON.
```

(There is one exception. We will set both positions 3 and 6 to on during calibration with a voltmeter in the next section.)

* Do not attempt to measure high voltages with VOTEM.

* Do not attempt to measure negative voltages with VOTEM. Although VOTEM is protected from high voltages and voltages of the wrong polarity, the V/F can still be damaged if a large enough current or negative current is forced upon it. <u>ALWAYS CHECK POLARITY BEFORE CONNECTING ANYTHING TO THE VOLTAGE INPUT.</u>

* Do not operate VOTEM without the protective plastic covers.

THE MACHINE LANGUAGE ROUTINE

A special Z80 machine language routine is required to operate VOTEM. The routine measures the rate of pulses coming into the computer's cassette input. The machine language routine will be called by a BASIC program in a USR function. A value which is proportional to the pulse rate will be returned to the BASIC program. This machine language routine will be used in all of your subsequent software so you need to permanently record it on tape for future use.

There are many ways of getting BASIC and machine language code to coexist in a program. There are also ways of getting into trouble by mixing the two in certain ways, producing unpredictable results and system crashes. We have found that in most cases, embedding the machine language in a REM statement works well. The technique is described below.

According to the ZX81 BASIC Programming Manual, the first byte of a BASIC program is at memory location 16509 (decimal). This location contains the most significant byte of the first line number in the program. The next location contains the less significant byte. The next two bytes represent the length of the first line. And finally, the next location, which is 16513, contains the first keyword-character code of the first statement. If the first statement in the BASIC program is a REM statement then the character code for the REM keyword (234) will appear in that memory location. We can place our machine code beginning at the next location, 16514. We can reserve as much space as we have memory by typing in a very long REM statement. The machine code can then be POKED sequentially into memory starting at location 16514.

INSTRUCTIONS

(1) Before proceeding you may wish to connect VOTEM to the computer. This will allow you to test the programs in the following sections without having to disconnect power and thus clearing the programs from memory. Refer to the previous section before applying power to VOTEM.

(2) Start by typing line number 1 as a REM statement followed by 29 characters; they can be spaces, periods, numbers or anything. Then key in the rest of the program listed below.

Program for Entering Machine Code in REM Statement

```
 1 REM 12345678901234567890123456789
10 FOR I=16514 TO 16542
20 INPUT P
30 POKE I,P
40 NEXT I
50 FOR I=16514 TO 16542
60 PRINT PEEK(I),"HIT ENTER"
70 INPUT Z$
80 SCROLL
90 NEXT I
```

(3) Run the program. The cursor should have changed to the inverse 'L' indicating that the computer is expecting a numerical input.

(4) Enter the following list of numbers. Hit 'ENTER' (or 'NEW LINE for ZX80s) after each entry. When you have entered the last number the computer should display the first number you entered. Hit ENTER to get the next and so on. Use this to double check your entries. Here is the list.

```
33
139
64
1
0
0
17
0
0
27
122
179
200
219
254
7
48
247
3
27
122
179
200
219
254
7
56
247
233
```


(5) Once you have double checked your entries, list the program. That first REM statement should look like a garbled up mess- a good sign that you did it right. Now erase the rest of the program, statements 10 through 90, by simply typing in the line numbers and hitting 'ENTER'.

(6) SAVE the remaining program, which consists of only the REM statement. Name the proram whatever you wish. Use the single cable provided with VOTEM. Connect it between the MIC jack on your tape recorder and the MIC jack on the computer. Once you have SAVEd the program, you may remove the cable and connect it between the TAPE SIG IN jack on VOTEM and the EAR jack on the the tape recorder. This configuration will allow you to LOAD programs into the computer as described in the section entitled "TAPE SIGNAL MONITOR AND CONDITIONER". Disconnecting this cable while the computer is running will not affect the power supply voltage to the computer and will not cause loss of memory. Of course, you may wish to use an additional cable and avoid the trouble, although it is not a necessity.

You now have the machine language routine in the computer's memory and also on tape. This is referred to as

1 REM ###(machine code)###

in some of the program listings throughout the rest of this manual. It **MUST ALWAYS BE THE FIRST LINE** of all of your programs dealing with VOTEM. For those that are interested in the gory details, a Z80 assembly language source listing of the routine is located in the appendix.

CALIBRATION

This section describes the necessary procedure for calibrating VOTEM for reading voltage and temperature. The purpose of the programs listed in this section is to determine the necessary coefficients that are unique to your particular system. The numbers you obtain are to be used by all future programs involving VOTEM. It is VERY IMPORTANT THAT YOU CAREFULLY FOLLOW THE INSTRUCTIONS IN THIS SECTION, for the accuracy of your future measurements will depend on the values obtained here!

VOLTAGE CALIBRATION USING BUILT-IN REFERENCE

The voltage measurement performance of your system will depend on how accurately you know the reference voltage used to calibrate it. Calibrating your system for voltage measurement will require an accurately known, stable DC voltage source. We will describe a calibration method using the built-in reference of VOTEM. This voltage reference is rock stable and accurate to within 5%. In other words, the built-in reference is somewhere between 0.95V and 1.05V. It is therefore advisable to measure the output voltage reference with a high quality voltmeter.

Voltage Calibration Instructions

(1) With the REM statement (the one with the embedded machine language routine) still in memory, key in the rest of the program below. If the REM statement is not still in the computer's memory then you must go back to the last section or LOAD it in if you have it on tape.

(2) If you have access to a voltmeter follow this step. Otherwise you can assume the reference to be exactly 1.000V, write that in the space provided and go on to step 3. As stated above, this assumption is good to within a 5% certainty. To measure the output reference voltage of VOTEM set the switches as follows:

	1	2	3	4	5	6	7	8
X=on								
O=off	O	O	X	O	O	X	X	O

With the switches set to the as above, the built-in reference voltage will appear at contacts #1 and #2 of the miniature screw terminals. The reference voltage can be measured at these contacts using a high impedence voltmeter, with the positive lead at contact #2 and the negative lead at contact #1. A poor quality voltmeter may have a low enough impedence to significantly load the reference voltage output and will lead to erroneous readings. Once the reference voltage has been determined write it down in the space provided.

VREF = ____________________ volts

(voltage reference)

(3) Run the program listed below. The switches should be set as in the previous step. Leave the voltmeter connected if you are using one. The screen should go blank for about a second before displaying:

ENTER VREF

If the screen goes blank for more than a couple of seconds or if the computer acts strangely then it means that your machine code is bad. If this is the case, you will have to reset the computer (by disconnecting power) and reenter the machine code as described in the previous section.

Note: Bear in mind that an external voltage reference can also be used for calibration purposes. Any stable voltage reference between +0.5V and +1.0V will do as long as it is accurately known; the built-in reference is perhaps more convenient. If an external reference is used, switch position 3 should be off.

(4) Type in the reference voltage that you measured above or just type in 1 if you did not go through the procedure of measuring the actual voltage reference output with a voltmeter. Hit ENTER and the computer will repeatedly display the acquired count from VOTEM.

(5) Now hit any key (except space) and the computer will display the voltage calibration coefficient. Write these down in the space provided. They will be used in your future voltage measurement programs.

VC = ____________________ volts per count

(voltage calibration coefficient)

Typical value for VC is 0.000044 volts per count.

Voltage Calibration Program

```
   1 REM S▒RND"   )   .?▒COS <= RE
TURN ▒K RUN ▀.?▒COS <= RETURN ▒5
 RUN DIM
  10 FAST
 100 PRINT "ENTER VREF"
 110 INPUT VREF
 120 LET COUNT=USR 16514
 130 CLS
 140 PRINT COUNT
 150 PAUSE 200
 160 POKE 16437,255
 170 IF INKEY$="" THEN GOTO 120
 180 LET VC=VREF/COUNT
 200 PRINT "VC = ";VC
 999 REM -NOTE- LINE 160 IS FOR
          ZX80 ONLY.
```

TEMPERATURE PROBE CALIBRATION

With the help of the program listed below we will determine the calibration coefficients for measuring temperatures with the external temperature probe. This will require two reference points. That is, we will obtain the output pulse rates of VOTEM with the temperature probe at two precisely known temperatures. Once these pulse rates are obtained the coefficients, slope (TS) and offset (TO), are automatically calculated and displayed by the program.

Temperature Probe Calibration Instructions

(1) With the REM statement (the one with the embedded machine language routine) still in memory, key in the rest of the program listed below. If the REM statement is not still in the computer's memory then you must go back to the last section or LOAD it into memory if you have it on tape.

(2) Set the switches on VOTEM as follows.

	1	2	3	4	5	6	7	8
X=on								
O=off	O	O	O	O	X	O	X	O

(3) Connect temperature probe to screw terminals, with gold lead at#3 and silver lead at #4.

(4) Immerse the probe in an ice-water slurry. Do not use ice cubes but rather shaved or crushed ice. Mix well and allow the slush to equilibrate for several minutes. Be sure the probe is totally immersed and is not in contact with the walls of the container. It is best to use some sort of insulated container or a thermos bottle to contain the ice-water slurry.

(5) After the probe has remained in the the ice-water slurry for a few minutes, RUN the program. The computer should display:

ENTER TL

Type in 0 then hit NEW LINE or ENTER. Note the number displayed on the screen. It will update about every five seconds or so. As long as the number is changing significantly from reading to reading the probe is not in equillibrium. When the numbers stop changing from reading to reading you may press any key except the SPACE key. This will advance the program to the next segment and the computer will display:

ENTER TH

(6) At this point remove the probe from the ice. It is now time to change over to the second reference point. A convenient reference temperature is that of boiling water. Immerse the probe in a container of boiling water or a thermos of freshly boiled water. Keep a cover over the thermos and allow the probe to equilibrate. Type 100 in response to the "ENTER TH" prompt.

(7) Once the probe has equilibrated press any key except the SPACE key. The computer will display the slope (TS) and offset (TO). Write these numbers down in the space provided below. These values will be used in your future temperature measurement programs and are only valid for this particular probe. The procedure must be repeated if you use a different probe.

TS = ______________________ counts per degree

(temperature probe slope coefficient)

TO = ______________________ degrees

(temperature probe offset coefficient)

Typical values are TS = -0.019 volts per degree C and TO = 298 degrees C.

Temperature Probe Calibration Program

```
   1 REM 5▒RND▪   )   .?▒COS <= RE
TURN ▒K RUN ▪.?▒COS <= RETURN ▒5
 RUN DIM
  10 FAST
  20 PRINT "ENTER TL"
  30 INPUT TL
  40 LET CL=USR 16514
  50 CLS
  60 PRINT CL
  70 PAUSE 200
  80 POKE 16437,255
  90 IF INKEY$="" THEN GOTO 40
 100 PRINT "ENTER TH"
 110 INPUT TH
 120 LET CH=USR 16514
 130 CLS
 140 PRINT CH
 150 PAUSE 200
 160 POKE 16437,255
 170 IF INKEY$="" THEN GOTO 120
 180 LET TS=(TH-TL)/(CH-CL)
 190 LET TO=-TS*CL-TL
 200 PRINT "TS","TO"
 210 PRINT TS,TO
 999 REM -NOTE- LINES 80 AND 160
         ARE FOR ZX80 ONLY.
```

Some Notes On Calibration For High Accuracy Measurements

To obtain highly accurate readings with the temperature probe some extra attention must be paid to detail. You must use pure water, preferabley distilled and deionized. You should carry out the calibration experiment in an insulated thermos or Dewar flask. The atmospheric pressure must be taken into account to determine the actual boiling point of the water. It is well known that Water boils at a lower temperature in areas of high altitude due to a lower average atmospheric pressure. You should determine the local atmospheric pressure with a mercury barometer to find the actual boiling point of water. Consult you local meteorlogical guru and physical chemist or apply the following equation. Be certain to use absolute pressure and not the relative sea level presure given by most TV reports.

$$T = \frac{9717}{1.987 * (19.74 - \ln P)}$$

where ln P is the natural logarithm of the absolute pressure expressed in torr or mm of mercury and T is the absolute temperature on the Kelvin scale (see page 4).

INTERNAL TEMPERATURE SENSOR

Unfortunately there is no convenient method for calibrating the internal temperature sensor. This sensor is located inside the V/F. Immersing the V/F in water could be disastrous. So, we must take at faith, the manufacturer's claim that the temperature output of the V/F tracks temperature at 1 millivolt per Kelvin. Our experience shows that this is actually pretty close to truth. However, a slightly better approximation is to assume that the temperature output tracks temperature according to the following equation:

Temperature (degrees K) = VT * 1000 / VREF

where VT is the voltage measured at the temperature output.

To measure temperature with the internal sensor set the switches as follows

	1	2	3	4	5	6	7	8
X=on								
O=off	O	O	O	X	O	O	X	O

Then simply read the voltage with VOTEM and convert it to temperature in software by using the equation above. See page 18.

MEASURING VOLTAGES AND TEMPERATURES

We will provide you with a few short programs that will enable you to carry out simple voltage and temperature measurements using VOTEM and your computer. After that it will be up to you to come up with your own unique applications. We hope that the following programs will provide you with enough insight to accomplish your goals.

First let's review and restate our requirements. You will need the following:

* The REM statement with the embedded machine code. See the section entitled THE MACHINE LANGUAGE ROUTINE.

* The voltage and temperature calibration coefficients. See the section entitled CALIBRATION.

* Proper connections. See the section entitled BEFORE OPERATING.

VOLTAGE MEASUREMENT

To measure a voltage between 0 and +1V make the connections to VOTEM and the computer as shown in the connection diagram in the appendix. Set the switches as follows.

	1	2	3	4	5	6	7	8
X=on								
O=off	O	O	O	O	O	X	X	O

Type in the program below. Save it on tape before proceeding. The value you recorded for the voltage calibration coefficient (VC) in the calibration section must be put into line 10. Run the program. The voltage appearing at the input will be displayed on the screen. Hit SPACE to stop the program.

Voltage Measurement Program

```
 1 REM ###( machine code )###
10 LET VC=(your value goes here)
20 LET X=16514
30 FAST
40 LET V=VC*USR X
50 PRINT V;" VOLTS"
60 PAUSE 50
61 POKE 16437,255
70 CLS
80 GOTO 20
```

Note: 30 is not necessary for ZX80
61 is not necessary for ZX81

If you do not have a 0 to +1 voltage source available, try measuring the voltage reference output. Set the switches as follows:

	1	2	3	4	5	6	7	8
X=on								
O=off	O	O	X	O	O	O	X	O

Run the program. You should get a value close to +1V. In fact it should be very close to your value for VREF.

You can also try measuring the voltage with the input switched to ground. Set the switches as follows:

	1	2	3	4	5	6	7	8
X=on								
O=off	O	X	O	O	O	O	X	O

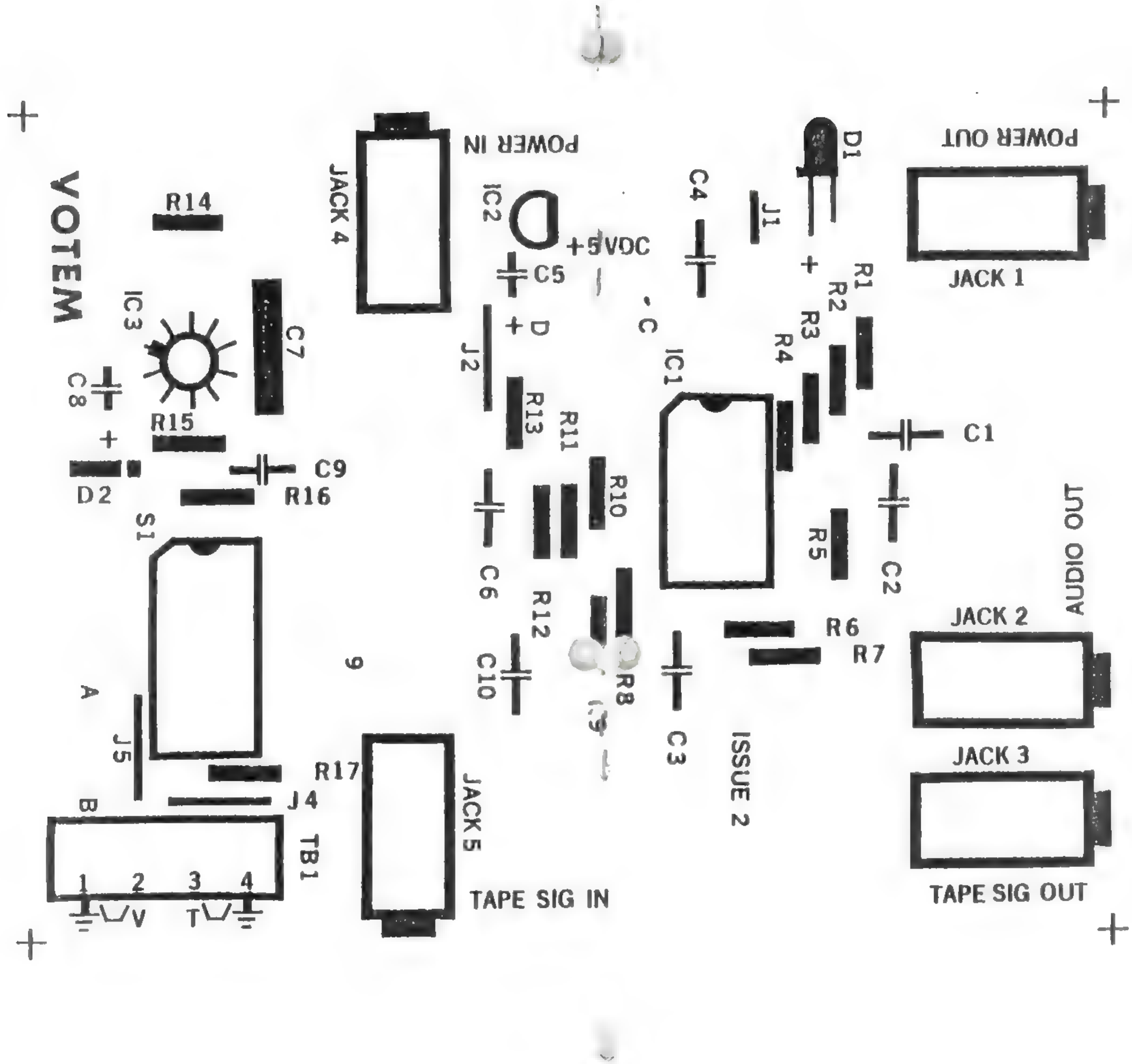
Run the program. The computer should display a value very close to 0V.

TEMPERATURE MEASUREMENT
(External Probe)

Make the connections as shown in the connection diagram in the appendix. The gold lead should attach to screw terminal #3 and the silver lead to #4. Set the switches as follows:

	1	2	3	4	5	6	7	8
X=on								
O=off	O	O	O	O	X	O	X	O

Type in the program below. Save it on tape before proceeding. The values you obtained for the temperature slope and temperature offset (TS and TO) calibration coefficients must be put into lines 10 and 20 respectively. Run the program. The temperature of the probe will be displayed on the screen. Hit SPACE to stop the program.


VOTEM
POWER IN
POWER OUT
JACK 1
JACK 2
JACK 3
JACK 4
JACK 5
+5VDC
AUDIO OUT
TAPE SIG IN
TAPE SIG OUT
ISSUE 2
IC1
IC2
IC3
D1
D2
S1
TB1
J1
J2
J4
J5
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
R1
R2
R3
R4
R5
R6
R7
R8
R10
R11
R12
R13
R14
R15
R16
R17
1
2
3
4
A
B
V
T

External Temperature Measurement Program

```
  1 REM ###( machine code )###
 10 LET TS=(Your value goes here.)
 20 LET TO=(Your value goes here.)
 30 LET X=16514
 40 FAST
 50 LET TC=TS*USR(X)+TO
 60 LET TF=9*TC/5+32
 70 PRINT TC;" DEGREES C"
 80 PRINT TF;" DEGREES F"
 90 PAUSE 50
 91 POKE 16437,255
100 CLS
110 GOTO 30
```

Note: 40 not necessary for ZX80.
91 not necessary for ZX81.

(Internal Sensor)

Set the switches as follows:

	1	2	3	4	5	6	7	8
X=on O=off	O	O	O	X	O	O	X	O

Type in the program below. Put in your value for VREF from the calibration section. Run the program. The temperature of the V/F converter will be displayed.

Internal Temperature Measurement Program

```
  1 REM ###( machine code )###
 10 LET VREF=(Your value goes here.)
 20 LET VC=(Your value goes here.)
 30 LET X=16514
 40 FAST
 50 LET V=VC*USR X
 60 LET TK=1000*V/VREF
 70 LET TC=TK-273.16
 80 LET TF=9*TC/5+32
 90 PRINT TK;" DEGREES K"
100 PRINT TC;" DEGREES C"
110 PRINT TF;" DEGREES F"
120 PAUSE 50
121 POKE 16437,255
130 CLS
140 GOTO 30
```

Note: 40 not necessary for ZX80.
121 not necessary for ZX81.

Try holding your finger on the top of the metal can of the V/F. You should notice a rise in temperature on the diplay.

TAPE SIGNAL MONITOR AND CONDITIONER

VOTEM also includes circuitry for conditioning and allowing you to monitor the signal from your tape recorder as it goes to your computer.

TAPE CONDITIONING CIRCUIT

The output of VOTEM connects to the tape input of your computer. Having to disconnect VOTEM each time you wanted to LOAD a program would be an inconvenience. Fortunately, the 7th and 8th positions of the DIP switch can be used to switch between the two. Position 7 selects the V/F section of VOTEM while position 8 selects the conditioned tape signal. **Only one of these should be on at a time.** Positions 1 through 6 select the analog inputs, so their configuration is irrelevant as long as no more than one of them is on at a time.

The tape signal is conditioned by a circuit known as a Schmitt trigger. With this circuit the signal is amplified and squelched of electrical noise such as tape hiss. The sensitivity of the tape conditioner is set at about 0.25V peak to peak. If desired, the sensitivity can be increased by increasing the value of R12. Increasing the sensitivity would allow you to use a lower volume setting on your tape recorder during LOADing.

TAPE MONITORING

VOTEM also provides you with two means (audible and visual) of monitoring the tape signal. The LED on VOTEM flashes each time a pulse is sent to the computer. This includes the pulses generated by the V/F. Most of the time the LED will be flashing so fast, it will appear to be on continuously. When monitoring the tape signal, however, it will be flashing slow enough to detect. For audio monitoring, a speaker or ear phone may be connected through the jack labeled "AUDIO OUT".

FREQUENCY MEASUREMENT

The tape signal input of VOTEM can be used to condition pulses from various sources, thus providing you with frequency meter that will count beyond 30KHz. As we said before, the count returned from the machine language routine is proportional to the frequency at the tape input. To convert the count to a real frequency requires that we know our system clock frequency. The frequency at the input is then calculated by the following equation:

$$F = \text{COUNT} * \frac{F_{sc}}{46 * 65536}$$

where F_{in} is the input frequency and F_{sc} is the system clock frequency.

Remember, the system clock on the Sinclair may not be exactly 3.25MHz as stated in the literature. It can be as much as a few percent from that value. Therefore, to measure frequency accurately with the Sinclair computer will require that you accurately know your computer's clock frequency. The easiest and perhaps most reliable way of determining your system's clock frequency is by measuring it with a good frequency meter. Consult the schematic for the computer to determine a point for connecting a frequency meter. You do not need to know your system clock frequency for measuring voltage and temperature.

Another way of determining your system clock frequency is by calibrating your system against a known stable frequency source. Connect the frequency source to VOTEM and set the switches as you did for tape input. Have the computer display the COUNT and calculate the system clock frequency from that. If you live in the U.S. one source is the 60Hz AC in the power line. In most cases this frequency source can be can be accessed on VOTEM by installing jumper J2 and a 0.1 microfarad capacitor where C6 is labled on the circuit board. The 120Hz ripple from the power supply should trigger the tape signal conditioner, providing you with a stable reliable frequency. Remember to disconnect J2 or C6 when you want to go back to tape. <u>Failure to do this could result in damage to your tape recorder.</u> We would prefer you find some other frequency source for calibration, but we felt that this would be handy for those who are careful.

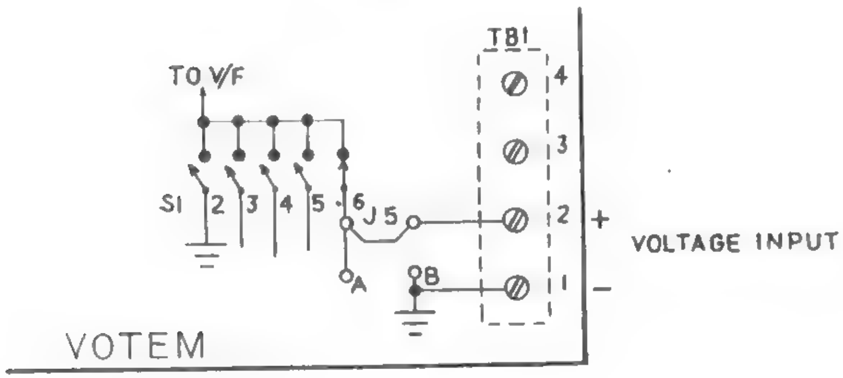
APPLICATIONS AND NOTES

The many applications possible with VOTEM are limited only by your imagination. VOTEM can be interfaced to a variety of instruments and devices. We will touch on just a few.

Expanding the Input Voltage Range

Any quantity that can be represented or transformed into a voltage can be measured with VOTEM. The only hitch is that the voltage must be shifted, amplified or attenuated so that it falls within the range of VOTEM's allowable input of 0 to +1V. Attenuation is easy. Provision for an on-board 2-resistor voltage divider allows you to expand the input voltage range beyond +1V. Use the equation given below to determine the values for the resistors to use for the desired full scale voltage, V_{fs}.

$$V_{fs} = \frac{R_a + R_b}{R_b}$$

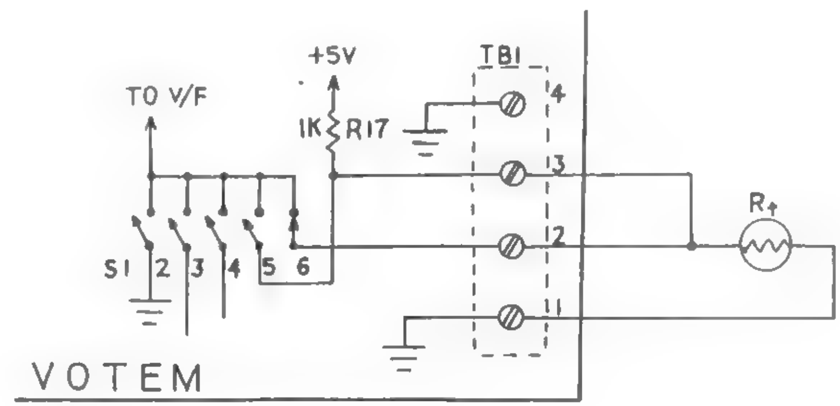


R_a replaces jumper J5 and R_b is connected between A and B as labeled on the circuit board. For example, to set the full scale input voltage to +10V, choose R_a = 9K ohms and R_b = 1K ohms. Use 1% precision resistors and be sure to specify the resistor values high enough as not to exceed their rated power. We recommend calibrating VOTEM again, with an external voltage source, after installing R_a and R_b. With a sensitivity on the order of five hundredths of a millivolt, it is doubtful that you would ever need to amplify. Shifting the input voltage would require mixing the input signal with another voltage source.

Resistance Thermometer Probe

Platinum resistance thermometer probes are available at a moderate price.[*] These devices, also known as RTDs, exhibit a change in resistance as a function of temperature. They are very accurate, repeatable and are normally specified to operate within a range of -200 to +600 degrees C. The resistance of a typical platinum RTD is about 60 ohms at -200 degrees, 100 ohms at 0 degrees and about 250 ohms at 400 degrees C. Connecting one to VOTEM is easy. Replace R17, a 4.7K ohm resistor, with a 1% precision 1K ohm resistor and connect the RTD as shown below. The voltage in will be a function of the resistance of the RTD. The function between the resistance (R_t) and temperature is not exactly linear, however it is known. A chart or equation relating resistance and temperature should be provided with the probe. The circuit below should enable you to convert temperatures between -200 and +400 degrees C. The voltage, V_t, appearing at the input is related to the values of R17 and R_t by the voltage divider equation.

$$V_t = \frac{5 * R_t}{R_t + 1000}$$



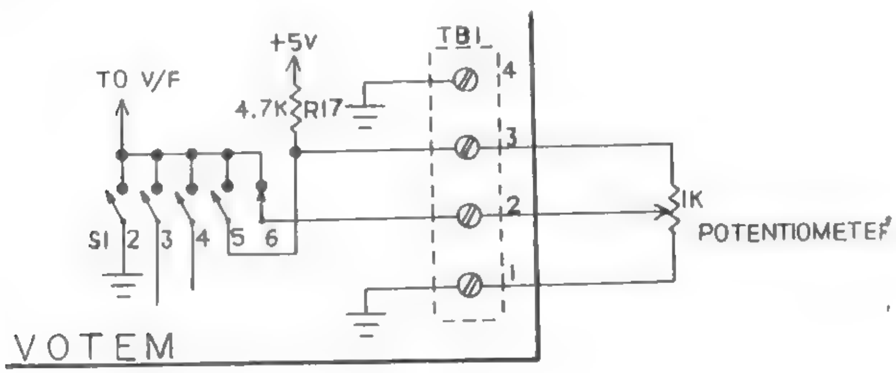
[*] Omega Engineering, Inc.
One Omega Drive
Box 4047
Stamford, Connecticut 06907
(203) 322-1666

Position Transducer (Game Paddle)

A 1K ohm variable resistor or potentiometer can serve as a position transducer. The amount of rotation (or linear position on a slide pot) is translated to a ratio of resistances. This ratio can easily be determined with VOTEM. Use as a game paddle would require special software not provided here. However, it should be relatively easy to develope some appropriate software. One should bear in mind that on the Sinclair computer we only need a resolution of 1 in 64 for plotting a point on the X-axis. The machine routine could be modified to read for only a few milliseconds instead of almost one second. The trade off is between speed and resolution. The point is that we don't need much resolution to operate a game paddle. Locations 16521 and 16522 contain the low and high bytes, respectively which determine the length of time the machine language stays in the loop. A resolution of 1 in 256 is obtained by changing the following memory locations in the machine language routine.

```
POKE 16521,0
POKE 16522,2
```

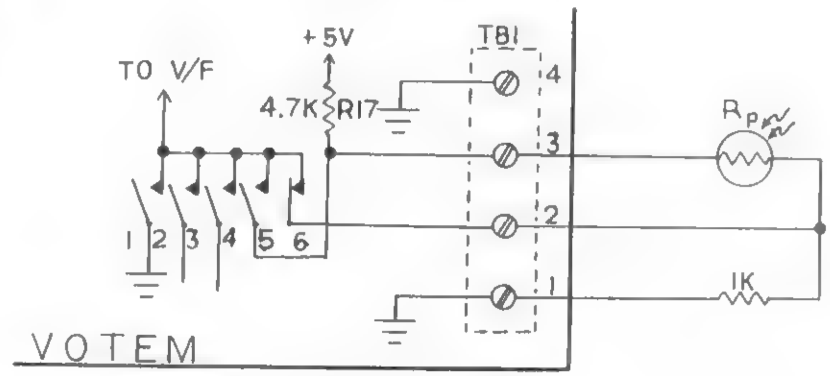
The machine language routine will then execute in less than 5 milliseconds.



Light Detector

A cadmium sulfide photo resistor can be used as a light detector. The resistance of this device in total darkness is about 500K ohms and about 100 ohms when exposed to bright light. Connect as shown below and you have a light meter, uncalibrated of course. A crude method of calibration might consist of measuring the resistance (R_p) with 1,2,3... and so on, lit candles (placed a specified distance from the photocell-detector)in a dark room. A better way would be to calibrate it against a good light meter. The equation relating the input voltage (V) to the resistance (R_p) of the photocell is shown below.

$$V = \frac{5 * 1000}{1000 + 4700 + R_p}$$



Data Acquisition

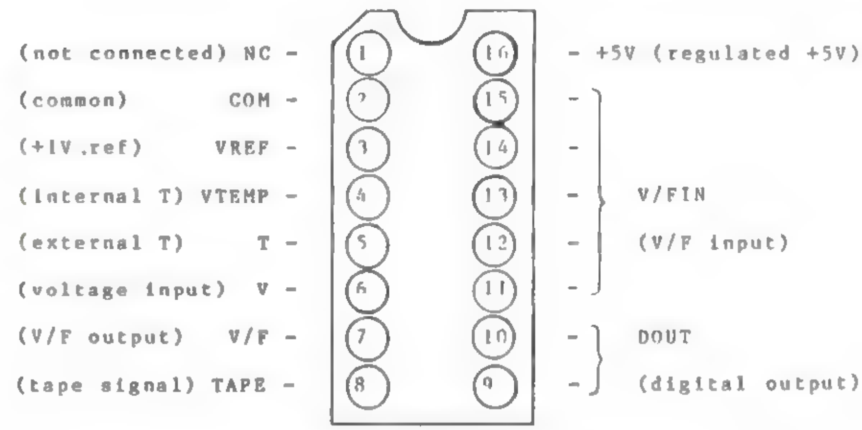
It is often desirable to let the computer automatically read and store data that it collects from the outside world. This process is called data acquisition and if the computer samples data at defined periodic intervals, it is called timed data acquisition. The program below illustrates the process. A menu gives the user several options, including listing, displaying and plotting temperatures of the probe every five minutes. (The interval could be changed to hours or even days simply by using a large value in the delay loop at line 1050.) Another option is collecting the data. As each data point is collected, the temperature is displayed and the point is plotted. The acquisition process can be stopped by pressing any key (except SPACE) while the program is in the delay loop. A maximum of 50 data points can be collected. More could be collected with a 16K system. The program takes advantage of the SLOW mode on the ZX81 but it could be modified to run in FAST-mode-only on the ZX80.

Temperature/Timed Data Acquisition Program (2K RAM)

```
   1 REM ###( machine language routine )###
   5 DIM T(50)
 100 CLS
 140 PRINT "1- ACQUIRE",,"2- LIST",,"3- PLOT",,"4- CURRENT"
 160 INPUT G
 170 GOSUB G*1000
 199 GOTO 100
 200 FAST <--- routine to get count and convert to temp
 210 LET TC=INT ((-slope*USR 16514+offset)*10)/10
 220 LET TF=INT (10*(9/5*TC+32))/10
 230 PRINT AT 10,23;TC;"  C  "
 240 PRINT AT 12,23;TF;"  F  "
 250 SLOW
 299 RETURN
1000 LET P=0   <--- routine to acquire data
1010 CLS
1020 FOR I=1 TO 5
1030 PRINT AT (I-1)*4,0;100-(I-1)*20    <--- label axis
1034 PRINT AT 21,I*5+1;I*2
1036 NEXT I
1039 IF P THEN RETURN
1040 FOR N=1 TO 50
1050 FOR I=1 TO 180              <--- delay routine determines
1051 IF INKEY$<>"" THEN RETURN        sampling interval
1052 NEXT I                            (use PAUSE for ZX80)
1060 GOSUB 200
1070 LET T(N)=TC
1080 PLOT N+3,2+T(N)/2.5
1190 NEXT N
1999 RETURN
2000 CLS
2040 FAST
2080 FOR J=0 TO 40 STEP 10
2100 FOR I=1 TO 10
2120 PRINT T(I+J)
2140 NEXT I
2150 PRINT ,J+10
2160 INPUT Z$
2170 CLS
2180 NEXT J
2999 RETURN
3000 LET P=1       <--- routine to plot collected data
3020 GOSUB 1005
3040 FOR N=1 TO 50
3060 PLOT N+3,2+T(N)/2.5
3070 NEXT N
3090 INPUT Z$
3999 RETURN
4000 GOSUB 200     <--- routine to print current temperature
4020 INPUT Z$
4999 RETURN
```


Connecting VOTEM to an External Switch Network

You may wish to replace the DIP switch with an external switching network. A single pole, 5-position rotary switch could be used to switch the various analog inputs, while a single pole, two-position toggle switch could be used to switch between the V/F and TAPE. Simply remove the DIP switch from the socket and plug in a DIP jumper-cable wired to the appropriate switches at the other end. Follow the diagram shown below of the socket to wire the jumper-cable.



Top view of signals appearing at 16-pin DIP socket.

Power Supply and Multichannel Considerations

VOTEM typically draws about 25 milliamperes of current from the power supply. If you are using an add-on memory pack and are powering your system from the calculator-type power supply that came with your computer, then the 25 mA of current drawn by VOTEM could be the "straw that breaks the camel's back". This problem could present itself in many ways, most of the time resulting in catastrophic system crashes. There are several ways to correct the problem. You can buy or build a heftier power supply, or you can add more filtering, to reduce the A.C. ripple, in the form of a capacitor to the present supply. Two points on the circuit board, labeled "C" and "D", are provided for this. A 100 mF (or greater), 25V electrolytic capacitor will significantly reduce power supply ripple. Be sure to observe the proper polarity when installing the capacitor. See the schematic. Also, removing the LED may help. The LED is the single most current consuming component on the board, drawing about 10 mA; removing it reduces VOTEM's total current consumption by 40 percent.

Since VOTEM is a relatively low-current device, battery operation is feasible. The unit could operate for several hours on a single 9V alkaline transistor radio battery. Battery operation may be well suited certain remote data collection applications. VOTEM can be located at the signal source and the data can be sent digitally to the computer, thus reducing possibly of noise being introduced.

It is often desirable to collect data from several sources. For example, multipoint temperature sensing is required to calculate the efficiency of a solar collector. Typically, one records the temperature at the inlet and at the outlet of the collector. Unfortunately one VOTEM unit can not do this job alone. However, two or more units connected to an external input port can be used. (Each must be individually calibrated.) There is only one cassette input, so an external port is necessary. Each VOTEM can be connected to different bits of a single input port, or each unit could be connected to the same bit of different ports. In either case the machine language routine would have to be rewritten or modified to accomodate the change in hardware. Connecting the units to bit 7 of different ports would require changing only the port address in the routine. Also, if the port is memory mapped, the "IN A,INPORT" instructions will have to be changed to "LD A,(nnnn), where nnnn is the address of the memory mapped port. See the Z80 assembly language listing and accompanying text in the appendix.

TELL THE WORLD ABOUT VOTEM

If you make any significant discoveries or come up with some unusual or particularly useful application of VOTEM, why not publish an article about it? There are several organizations who would pay you money for your published work. You may want to include diagrams of any external hardware that you use along with program listings of the application program. Below are a few publications which have published articles concerning the ZX80/81. There are certainly many other publications that feature articles on the Timex/Sinclair computer.

SYNC Magazine
Paul Grosjean, Editor
39 East Hanover Ave.
Morris Plains, NJ 07950

SYNTAX
Ann Zevnik, Editor
RD 2, Box 457
Harvard, MA 01451

Byte Magazine
Editor
POB 372
Hancock, NH 03449

Computers and Electroics
Leslie Solomon, Editor
1 Park Ave.
New York, NY 10016

THE FINE PRINT

VOTEM is not to be used as, or in any part of, a life supporting or life sustaining system. Moreover, VOTEM should never, in any fashion, be connected, directly or indirectly, to the human body. Down East Computers cannot be held responsible for any damage or personal injury resulting from the use or misuse of VOTEM. Though every effort has been made to insure all information in this manual is accurate, Down East Computers cannot be held liable for any misinforamtion that may result therefrom.

Down East Computers will replace faulty or missing components as long as they are reported within 15 days after customer receives VOTEM kit. Components which have been damaged from heat or misuse by the customer will require a parts charge which will depend on the item(s) being replaced. Kits will be repaired and returned in working order by Down East Computers for a flat fee of $20.00. The $20.00 fee excludes repairs to the printed circuit board. Assembled versions of VOTEM are warrented for a period of 30 days after customer receipt. Any items returned must include a description of problem. Please check carefully all connections, switch settings and software before returning any item.

Interfacing VOTEM to Other Z80 Systems

VOTEM can be connected to any computer that will accept a TTL level input. Most computers have parallel input ports that are TTL level compatible. One bit of a parallel input port is all you need to connect VOTEM. However, this does not guarentee operation. Some sort of machine language software frequency counter routine is also necessary. The routine has to be in machine language for the required high-speed execution. Below is the Z80 assembly language listing of the machine language routine used throughout this manual. It would not be very difficult for an experienced hacker to implement the routine below on practically any Z80 microprocessor based system. Systems other than Z80 will require some sort of similar machine language pulse counting routine.

As written, the routine expects the input to appear at bit 7 of the input port. If bit 7 is not available, the routine can be modified to work with any of the 8 bits of the available port. Simply change the "RLCA" instructions to "BIT n" and change the "JR C" and "JR NC" instructions to "JR Z" and "JR NZ" respectively. To convert the count returned in BC to frequency, the count-to-frequency formula shown on page 20 will have to be changed by substituting the 46 with 47 and F_{sc} with the system clock frequency of the particular Z80 computer.

Once the machine code is installed on the system, use the BASIC programs in this manual to do the necessary calibration and measurement. The programs will, no doubt, have to be modified for the particular dialect of BASIC.

The timing capacitor (C7) on the V/F sets the full scale frequency output; it may have to be changed if the particular Z80 system is not running at or near 3.25 MHz. Use the following formula to determine the optimum value, C, of the timing capacitor according to the particular system clock frequency, F_{sc}. It should be of high quality, i.e., low leakage and low temperature coefficient.

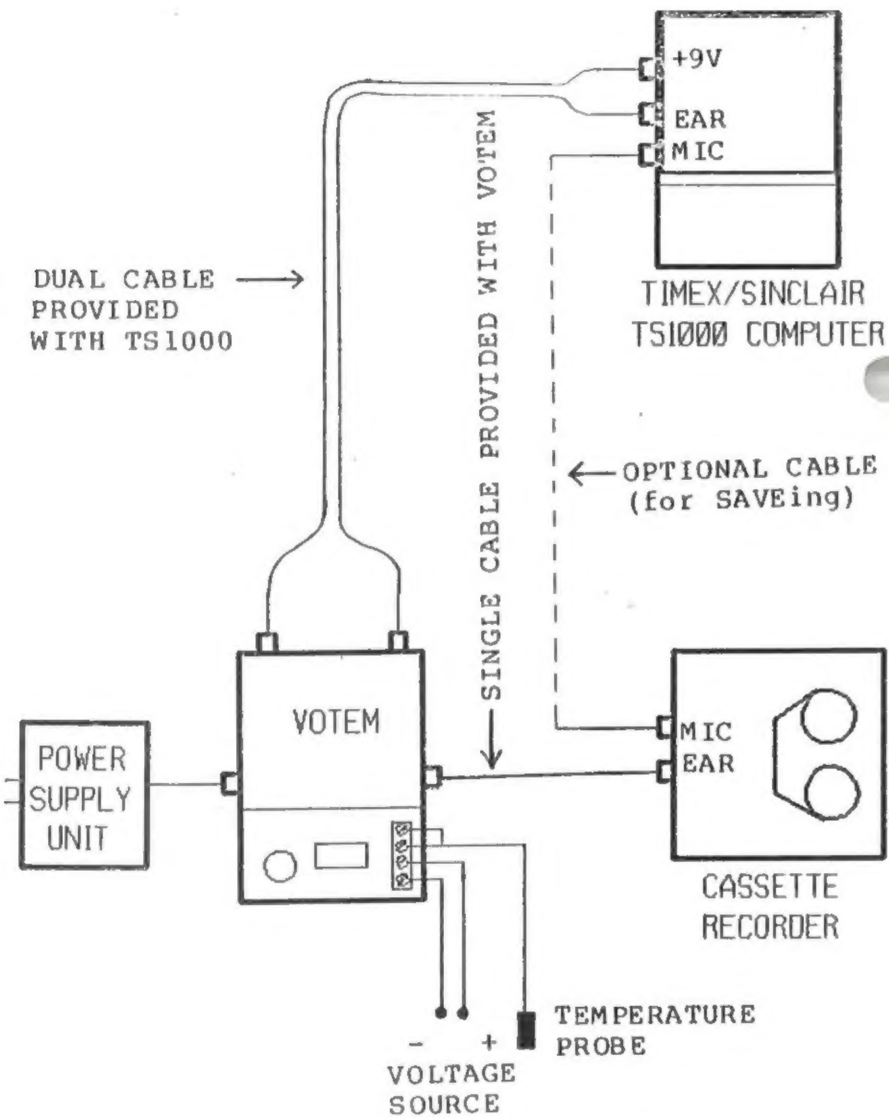
$$C = \frac{3.25}{Fsc * 390} \quad \text{(approx.)}$$

C is in pF and Fsc is in MHz.


```
;*********************************************************
;                                                        *
;                      ZCOUNT                            *
;                                                        *
;            Z80 pulse counting routine                  *
;                        by                              *
;                    Alger Salt                          *
;                     6-7-82                             *
;                                                        *
;     A count which is proportional to the frequency     *
;   of pulses present at bit 7 of port INPORT is         *
;   returned in BC.  Sampling rate is proportional       *
;   to the value set in DE.                              *
;                                                        *
;                                                        *
;                                                        *
;*********************************************************

                    INPORT  EQU   0FEH
                            ORG   04082H
4082  21 408B               LD    HL,LOOP1    ;Load HL with LOOP1.
4085  01 0000               LD    BC,0000H    ;Initialize count.
4088  11 0000               LD    DE,0000H    ;Initialize interval.
408B  1B            LOOP1:  DEC   DE          ;Decrement interval.
408C  7A                    LD    A,D         ;Is it zero yet?
408D  B3                    OR    E
408E  C8                    RET   Z           ;Return if it is.
408F  DB FE                 IN    A,(INPORT)  ;Get state of input
4091  07                    RLCA              ;Is input low?
4092  30 F7                 JR    NC,LOOP1    ;Jump if it is.
4094  03                    INC   BC          ;Got transition. Increment count.
4095  1B            LOOP2:  DEC   DE          ;Decrement interval.
4096  7A                    LD    A,D         ;Is it zero yet?
4097  B3                    OR    E
4098  C8                    RET   Z           ;Return if it is.
4099  DB FE                 IN    A,(INPORT)  ;Get state of input.
409B  07                    RLCA              ;Is input high?
409C  38 F7                 JR    C,LOOP2     ;Jump to LOOP2 if it is.
409E  E9                    JP    (HL)        ;Else jump to LOOP1.
                            END
```

VOTEM CONNECTION DIAGRAM



APPENDIX B

VOTEM: FACTS, FEATURES AND SPECIFICATIONS

VOLTAGE MEASUREMENT PERFORMANCE

Resolution	0.000044V (better than 14 bits.)
Accuracy (note 1)	+/- 0.2%
Input Resistance	250 Megohms (note 2)
Range (note 3)	0 to +1V (without divider network)
Linearity	0.1%

TEMPERATURE MEASUREMENT PERFORMANCE (specified in degrees C)

Resolution	better than 0.05
Accuracy (note 1)	+/- 0.5
Range	-25 to +125

POWER SUPPLY REQUIREMENTS (note 4)

Operating Voltage	+8V to +15V (unregulated DC)
Current Consumption	25mA (typical)
	15mA without LED

COMPUTER REQUIREMENTS

Timex TS-1000 or Sinclair ZX81. Will also work on ZX80 (w/8K-ROM). Basic measurements and operations require only 1K of RAM memory. Instructions and Z80 source code driver routine are provided for adapting to any Z80 based computer.

OTHER FEATURES

* Schmitt trigger conditioner circuitry for tape signal.
* LED tape LOAD monitor.
* Buffered audio output for speaker or earphone.
* Can be used as frequency counter from DC to beyond 30KHz.
* Functions are easily selected with 8-pole DIP switch.
* Self-contained in attractive (1" by 3" by 4") enclosure.
* Temperature probe for air and liquid temperature measurements.
* Glass-epoxy circuit board and high quality components used.
* Input connections are reliable miniature screw terminals.
* Instructions for interfacing to any Z80 system with 1-bit input.
* Easy-to-follow, 35-page manual can be purchased separtely.

Note 1: All calibration is done in software. The absolute accuracy of VOTEM will depend mainly on the choice of parameters and conversion factors used in the software. If the calibration procedures provided with VOTEM are followed then the accuracy should be as good or better than that specified above.

Note 2: High impedence measurements may require the removal of the input protection and filtering components, D2 and C8.

Note 3: The input voltage range of 0 to +1V can easily be expanded with an on-board resistor voltage divider network.

Note 4: VOTEM can be powered from the Timex/Sinclair computer's power supply. The VOTEM unit provides a power-in and power-out receptacles and also includes the proper connecting cable.

PARTS LIST

RESISTORS		(MARKINGS and/or COMMENTS)		REPLACEMENT CHARGE (+)
R1	220 ohm	Red/Red/Brown		.25
R2	680 ohm	Blue/Gray/Brown		.25
R3	33 Kohm	Orange/Orange/Orange		.25
R4	22 Kohm	Red/Red/Orange		.25
R5	100 Kohm	Brown/Black/Yellow		.25
R6	33 Kohm	Orange/Orange/Orange		.25
R7	22 Kohm	Red/Red/Orange		.25
R8	22 Kohm	Red/Red/Orange		.25
R9	22 Kohm	Red/Red/Orange		.25
R10	33 Kohm	Orange/Orange/Orange		.25
R11	33 Kohm	Orange/Orange/Orange		.25
R12	270 Kohm	Red/Purple/Yellow		.25
R13	4.7 Kohm	Yellow/Purple/Red		.25
R14	10 Kohm	Brown/Black/Orange		.25
R15	10 Kohm	Brown/Black/Black/Red/Brown	1%	.50
R16	4.7 Kohm	Yellow/Purple/Red		.25
R17	4.7 Kohm	Yellow/Purple/Red		.25

CAPACITORS				
C1	* .01 uF	103	ceramic disk	.35
C2	(Jumper or opt. 10uF cap for AC coupled output.)			.50
C3	* .01 uF	103	ceramic disk	.35
C4	* .01 uF	103	ceramic disk	.35
C5	4.7 uF	4.7 16	16V tantalum	.65
C6	not used			
C7	390 pF	390J TSC	precision polystyrene	.75
C8	4.7 uF	4.7 16	16V tantalum	.65
C9	* .01 uF	103	ceramic disk	.35
C10	* .01 uF	103	ceramic disk	.35

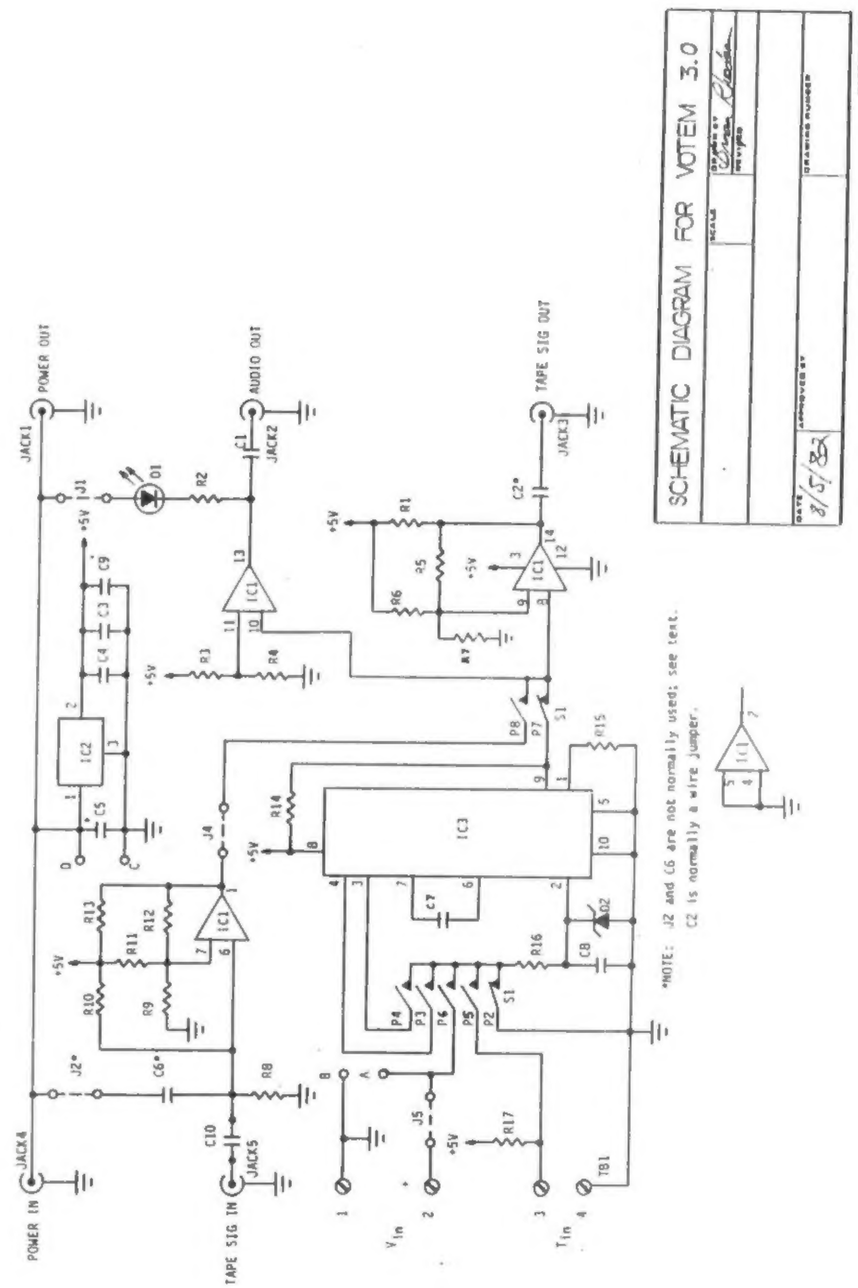
* These are not critical; yours may differ from list.

SEMICONDUCTORS				
IC1		339	comparator	1.25
IC2	+5V	78L05	regulator	1.50
IC3		AD537JH	V/F converter	10.00
D1			LED	.35
D2		1N746A	zener diode	.65
T1			temperature probe	5.00

CONNECTORS		
DS1	16-pin DIP socket	.50
DS2	14-pin DIP socket	.50
TB1	terminal strip	3.00
JACK1-5	5 phone jacks	.75 ea

MISCELANEOUS		
S1	DIP switch	2.00
F1-4	4 rubber feet	.50
PC1	circuit board	15.00
B1-2	2 binding posts + screws	.50
PVC1-2	2 plastic sheets	4.00
CC1	phone plug cable	1.50

(+) Replacement parts orders should be accompanied with $1 shipping and handling fee. Minimum order is $5.

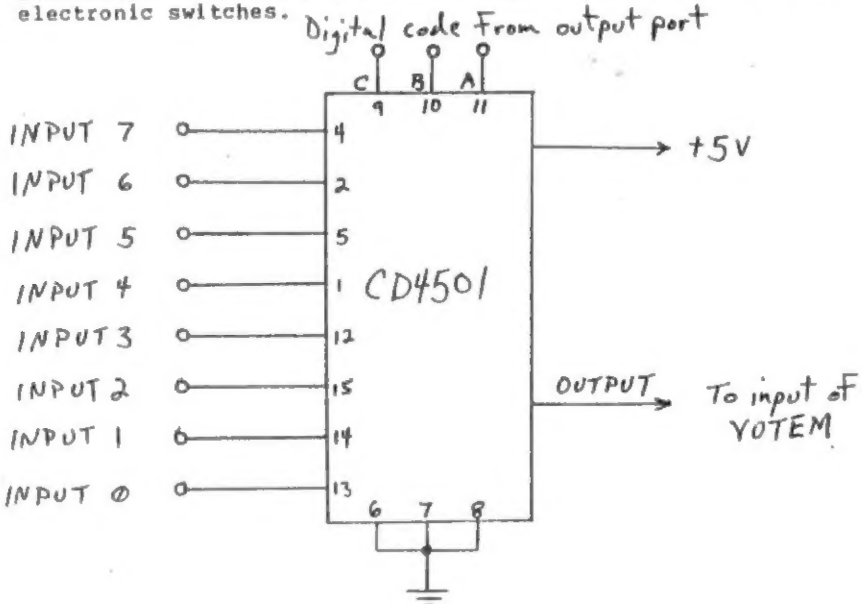


MORE THOUGHTS ON MULTICHANNEL CONSIDERATIONS

Another way to realize multichannel data collection is to switch the input of VOTEM between one of several. This can be done with a mechanical rotary switch, such as the type found in a TV tuner. However, you probably will want the computer to select the input. Byte-Back Company markets an input/output module The module consists of one 8-bit output port and one 8-bit input port. The output port drives 8 independent on-board relays. The relays could be used to switch several voltage sources or temperature probes into the single input on VOTEM.

If you have equipped your system with an output port you can use it to control a CD4051 8-channel analog multiplexer integrated circuit. The CMOS IC costs less than $3 and is available from most electronic supply companies. An analog multiplexer functions just like a rotary switch. The CD4051 routes one of eight inputs to a common output. The inputs are selected by means of a 3-bit digital (TTL) code. The circuit is shown below.

For critical measurements all inputs should be recalibrated with the multiplexer in place due to the non-zero "ON" resistance and the non-infinite "OFF" resistance of the electronic switches.



Note: The input to VOTEM, +5V and ground are available at the 16-pin DIP socket on VOTEM. See page 26.